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SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

SMBUD Project - Spark

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1 | Introduction

In this chapter will be presented the problem specification and the hypothesis under which the database is implemented.

1.1. Problem Specification

This project aims to build a database that handles scientific articles contained in the DBLP bibliography. In this implementation, our work will be focused on *Spark* technology, which is a distributed computing infrastructure that can process large amount of data in efficient day. To accomplish this we used the PySpark interface that allows us to interact with Apache Spark using python.

1.2. Assumption

- An author can't work for more than one organization for the same Publication
- As in the MongoDB implementation, a publication can be published only on one venue
- Venues with the same raw take place in the same city
- Venue is identified by raw field

2 | Conceptual Model

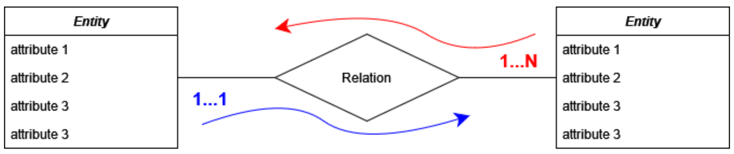


Figure 2.1: ER Diagram Organization

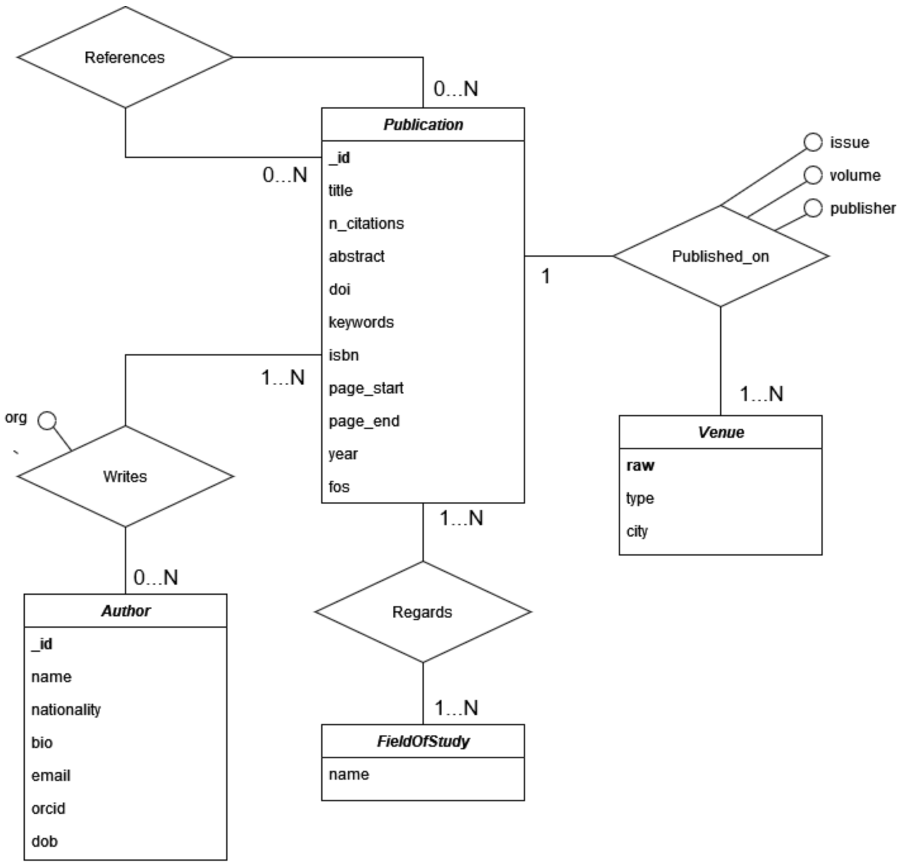


Figure 2.2: Conceptual Model

Note: in the conceptual model diagram, we highlighted the primary keys of the entities that are implemented as a collection: *Publication*, *Author* and *Venue*

The conceptual model above contains 4 main entities:

- **Publication:** represents all the scientific articles. Its attributes are: *_id, title, n_citations, abstract, doi, keywords, isbn, page_start, page_end, year, fos* and its organization will be presented later
- **Author:** it is the one who contributed to a publication. Its attributes are: *_id, name, nationality, bio, email, orcid, dob (date of birth)*
- **Venue:** it is where a publication is published or presented. Its attributes are: *raw, type, city*
- **FieldOfStudy:** this entity represents the subjects of the publication and its attribute is *name*

The 4 main entities just described, are related to each other through the following relationships:

- **References:** is the relationship between a *publication* and another *publication* cited by the first one
- **Published_on:** is the relationship between a *publication* and its *venue*. Its attributes are: *issue, volume, publisher*
- **Writes:** is the relationship between *author* and *publication* which features the affiliation property. We decided to design it with `org` as an attribute of the relationship, due to the assumption presented above
- **Regards:** is the relationship between a *publication* and its *fields of study*

Differences with *MongoDB* conceptual model:

- we added field `city` in *Venue* entity representing the location of the venue
- *Chapters* and *images* have been removed

3 Data Structure

In this part of the project we used the same two `JSON`s used in the *MongoDB* implementation. We only removed chapters inside articles and `_id` authors inside articles was renamed as `idAuth`. Also id and dates were reconverted in plain text because in *MongoDB* we needed to add them as special entities: `$oid` and `$date`.
This was done via the following lines of script:

- the **first line** is used for the `JSON` file containing the articles. The script removes `$oid`, to delete chapters field and to rename authors field *id* into *idAuth*
- the **second line** is used for the `JSON` file containing the authors. The script removes `$oid` and `$date`

```
cat dblp_sample_filtered.json | sed -E 's/\{"\$oid":(["a-z0-9]+)\}/\1/g' | jq 'del(.[].chapters)' | jq '.[].authors[] |= with_entries(if .key == "id" then .key = "idAuth" else . end)' > dblp_sample_filtered_spark.json

cat dblp_sample_reverted_filtered.json | sed -E 's/\{"\$oid":(["a-z0-9]+)\}/\1/g' | sed -E 's/\{"\$date":(["A-Z0-9:-]+)\}/\1/g' > dblp_sample_reverted_filtered_spark.json
```

4 | Dataframe Structure

4.1. Article Structure

```
root
|-- _id: string (nullable = true)
|-- title: string (nullable = true)
|-- authors: array (nullable = true)
|    |-- element: struct (containsNull = true)
|    |    |-- idAuth: string (nullable = true)
|    |    |-- org: string (nullable = true)
|-- n_citation: integer (nullable = true)
|-- abstract: string (nullable = true)
|-- doi: string (nullable = true)
|-- keywords: array (nullable = true)
|    |-- element: string (containsNull = true)
|-- isbn: string (nullable = true)
|-- page_start: string (nullable = true)
|-- page_end: string (nullable = true)
|-- year: integer (nullable = true)
|-- fos: array (nullable = true)
|    |-- element: string (containsNull = true)
|-- references: array (nullable = true)
|    |-- element: string (containsNull = true)
|-- issue: string (nullable = true)
|-- volume: string (nullable = true)
|-- publisher: string (nullable = true)
|-- venue_raw: string (nullable = true)
```

The structure just shown represents an *Article*; its attributes are:

- **_id** is the identifier of a publication.
- **title** represents the title of the publication.
- **authors** is an array that contains: `idAuth` of the authors of the article and the `org` field which contains their affiliations.

- **n_citation** is the number of times that the publication has been mentioned.
- **abstract** is a string containing a brief summary of the contents of the paper.
- **doi** Digital Object Identifier is a persistent and standardized identifier.
- **keywords** is an array containing keywords of the publication.
- **isbn** is an identification code of the venue of the publication.
- **page_start** defines the starting page of the publication.
- **page_end** defines the last page of the publication.
- **year** represents the year of publication.
- **fos** is an array containing the fields of study of the publication.
- **references** set of ObjectIds of the referenced articles.
- **issue** refers to how many times a periodical has been published during that year.
- **volume** is the volume of the venue in which the article has been published.
- **publisher** is the name of the publisher of the article.
- **venue_raw** is the name or the abbreviation of the venue (regardless the year, issue or volume) in which the publication was presented.

We moved `issue`, `volume` and `publisher` to the *Publication* structure because in this implementation we have a new collection for the *Venue*. This has been done because, as in previous projects, we decided to aggregate the venues with respect to the field `raw`.

4.2. Author Structure

```
root
|-- _id: string (nullable = true)
|-- name: string (nullable = true)
|-- nationality: string (nullable = true)
|-- articles: array (nullable = true)
|    |-- element: string (containsNull = true)
|-- bio: string (nullable = true)
|-- email: string (nullable = true)
|-- orcid: string (nullable = true)
|-- dob: timestamp (nullable = true)
```

The structure just shown represents an *Author*; its attributes are:

- **_id** is the identifier of an author.
- **name** is the name of the author.
- **nationality** is the nationality of the author.
- **articles** is a set of articles identifier of the publications of the author.
- **bio** is a string that describes the author.
- **email** is the email address of the author.
- **orcid** Open Researcher and Contributor ID is a unique identifier for authors of scientific articles.
- **dob** is the birth date of the author.

4.3. Venue Structure

```
root
|-- raw: string (nullable = true)
|-- type: integer (nullable = true)
|-- artIds: array (nullable = false)
|    |-- element: string (containsNull = false)
|-- city: string (nullable = true)
```

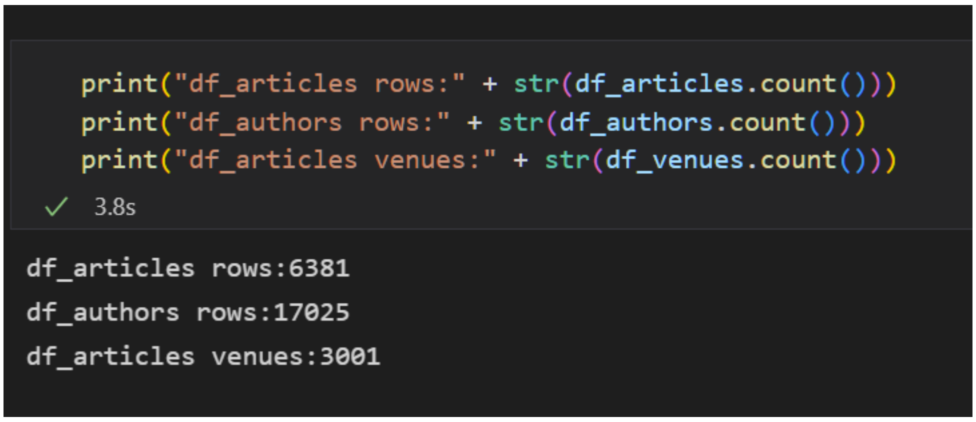
The structure just shown represents a *Venue*. This dataframe was obtained extracting venues fields from the Articles dataframe already imported. *Venue* attributes are the following:

- **raw** is the name or the abbreviation of the venue (regardless the year, issue or volume) in which the publication was presented.
- **type** indicates the type of the publication.
- **artIds** is a set of articles identifier associated to the venue.
- **city** represents the location of the venue; this attribute has been randomly populated.

Note that *artIds, city* where not present in the Article dataframe so have been generated during the creation of the venue collection.

4.4. Dataframe Analysis

These are the number of rows in our dataframes



```
print("df_articles rows:" + str(df_articles.count()))
print("df_authors rows:" + str(df_authors.count()))
print("df_articles venues:" + str(df_venues.count()))
```

✓ 3.8s

```
df_articles rows:6381
df_authors rows:17025
df_articles venues:3001
```

5 | Commands and Queries

5.1. Commands

We have identified the following `INSERT` and `UPDATE` commands to show the system basic functionalities.

5.1.1. Insert a new author

Assuming it is not present in the dataset, we created a row for the new author and we added it into the *Author*'s dataframe.

```
new_author = Row(
    _id="638db170ae9ea0d19fad7a79",
    name="Emanuele Delle Valle ",
    nationality="it",
    articles=[],
    bio="Emanuele Della Valle holds a PhD in Computer Science from the \
        Vrije Universiteit Amsterdam and a Master degree in Computer Science\
        and Engineering from Politecnico di Milano. He is associate professor\
        at the Department of Electronics, Information and Bioengineering of\
        the Politecnico di Milano.",
    email="emanuele.dellavalle@gmail.com ",
    orcid="0000-0002-5176 -5885",
    dob= datetime.strptime("March 7, 1975", "%B %d, %Y")
)

df_authors = df_authors.union(spark.createDataFrame([new_author], schema = schemaAuthors))
```

5.1.2. Insert a new article

Assuming it is not present in the dataset, we created row with a new article written by the author created in section 5.1.1. In order to set the authors, we instantiated an array `new_authors`.

```
new_authors =  [Row("638db170ae9ea0d19fad7a79", "Politecnico di Milano"), Row("638db170ae9ea0d19fad7a7a", "Politecnico di Milano")]

new_article = Row(
    _id="638db237d794b76f45c77916",
    title="An extensive study of C-SMOTE, a Continuous Synthetic Minority Oversampling Technique for Evolving Data Streams",
    authors=new_authors,
    n_citation=3,
    abstract = "Streaming Machine Learning (SML) studies algorithms that update their models,\
        given an unbounded and often non-stationary flow of data performing a single pass. Online \
        class imbalance learning is a branch of SML that combines the challenges of both class imbalance\
        and concept drift. In this paper, we investigate the binary classification problem by rebalancing\
        an imbalanced stream of data in the presence of concept drift, accessing one sample at a time.",
        doi="10.1016/j.eswa.2022.116630",
    keywords=["Evolving Data Stream","Streaming","Concept drift","Balancing"],
    isbn="123-4-567-89012-3",
    page_start="39",
    page_end="46",
    year=2022,
    fos=["Computer Science","Stream Reasoning","Big Data"],
    references=["53e99fe4b7602d97028bf743","53e99fddb7602d97028bc085"],
    issue="1",
    volume="196",
    publisher="Elsevier",
    venue_raw="ESA"
)

```

```
df_articles = df_articles.union(spark.createDataFrame([new_article]))
```

5.1.3. Insert a new venue

Assuming it is not present in the dataset, we created a new row with the values for a new venue *ESA* hosted in *Montreal*.
Note: in field `artIds` we set the article created in section 5.1.2.

```
new_venue = Row(
    raw="ESA",
    type=1,
    artIds=["638db237d794b76f45c77916"],
    city="Montreal"
)

df_venues = df_venues.union(spark.createDataFrame([new_venue]))
```

5.1.4. Add a new article to its authors

Through this command we inserted the article created in section 5.1.2 to its authors. In order to do that, we selected the authors through the ids and we add the article id to their field `articles`.
Note: one of the author is the one created in section 5.1.1.

```
df_authors = df_authors.withColumn(
    "articles",
    f.when(f.col("_id") == "638db170ae9ea0d19fad7a79",
        f.array_union(df_authors.articles, f.array(f.lit("
                                            638db237d794b76f45c77916"))))\
    .when(f.col("_id") == "638db170ae9ea0d19fad7a7a",
        f.array_union(df_authors.articles, f.array(f.lit("
                                            638db237d794b76f45c77916"))))
    .otherwise(f.col("articles"))
)
```

5.1.5. Update the number of citations of referenced publications

Through the following snippet of code is possible to increment the `n_citations` field of the *Publications* referenced by the article created in section 5.1.2.

Note: field `n_citations` is updated for both the referenced articles.

```
df_articles = df_articles.withColumn(
    "n_citation",
    f.when(f.col("_id") == "53e99fe4b7602d97028bf743",
        df_articles.n_citation+1) \
    .when(f.col("_id") == "53e99fddb7602d97028bc085",
        df_articles.n_citation+1)
    .otherwise(f.col("n_citation"))
)
```

5.1.6. Deleting an author from the database

Through the following snippet of code is possible to delete an author from the database. In order to do that we started from filtering on the identifier of the author to be removed and we deleted it.

```
df_authors.filter(f.col("_id") == "638db170ae9ea0d19fad7a79").show()
df_authors = df_authors.filter(f.col("_id") != "638db170ae9ea0d19fad7a79
                                    ")
```

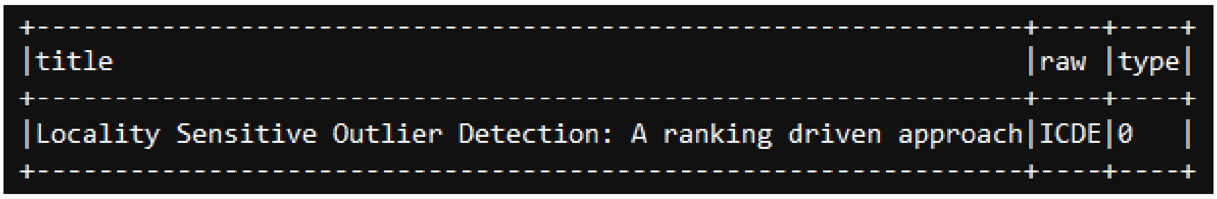
5.2. Queries

We have identified the following queries in order to show the system's basic functionalities. In the following sections title we wrote the basic requirements for every query, that, for ease of read, are represented as `SQL` clauses.

5.2.1. Query 1 - WHERE, JOIN

This query returns the type of the venue of an article with the following title: *"Locality Sensitive Outlier Detection: A ranking driven approach"*.
Description: starting from the articles dataframe, a join is performed with the venues dataframe on the article's `venue_raw` field. After that, we filter the articles with the given title. Finally, we project over title,venue raw and venue type.

```
df_articles.join(df_venues, df_articles.venue_raw == df_venues.raw, "
                                    inner")\
            .filter(f.col("title") == "Locality Sensitive Outlier
                                    Detection: A ranking driven approach
                                    ")\
            .select("title", "raw", "type")\
            .show(truncate=False)
```

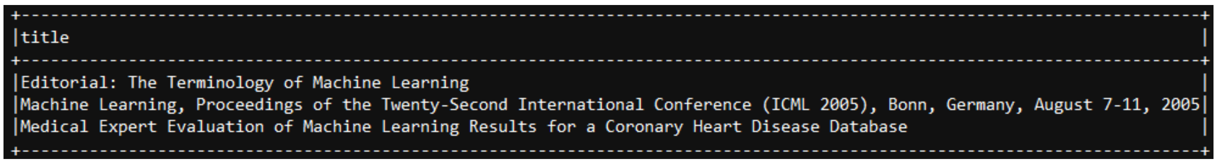


```
+--------------------------------------------------------------+----+----+
|title                                                         |raw |type|
+--------------------------------------------------------------+----+----+
|Locality Sensitive Outlier Detection: A ranking driven approach|ICDE|0   |
+--------------------------------------------------------------+----+----+
```

5.2.2. Query 2 - WHERE, LIMIT, LIKE

This query returns the articles whose title string contains *"Machine Learning"*.
Description: we filter the articles whose title contains "Machine Learning" using the like operator. Results are then limited to 3 tuples and projected over the article title.

```
df_articles.filter(f.col("title").like("%Machine Learning%"))\
            .limit(3)\
            .select("title")\
            .show(truncate=False)
```



```
+------------------------------------------------------------------------------------------------------------+
|title                                                                                                       |
+------------------------------------------------------------------------------------------------------------+
|Editorial: The Terminology of Machine Learning                                                              |
|Machine Learning, Proceedings of the Twenty-Second International Conference (ICML 2005), Bonn, Germany, August 7-11, 2005|
|Medical Expert Evaluation of Machine Learning Results for a Coronary Heart Disease Database                 |
+------------------------------------------------------------------------------------------------------------+
```

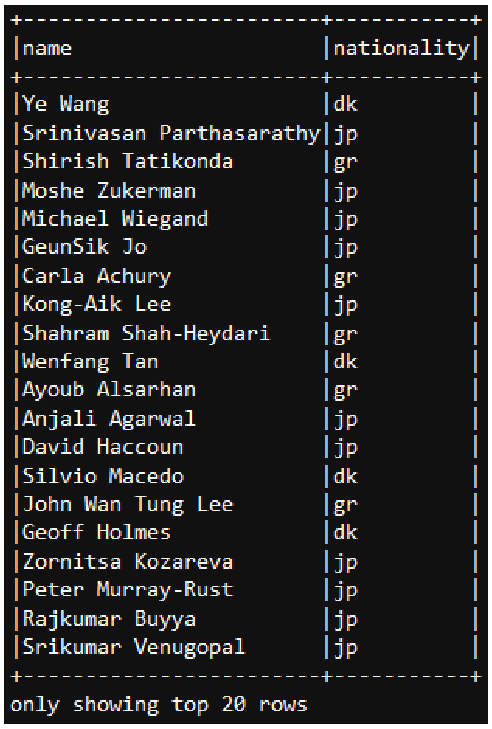
5.2.3. Query 3 - WHERE, IN, NESTED QUERY

This query finds authors that has the same nationality of at least one of the authors of *"Locality Sensitive Outlier Detection: A ranking driven approach"* article.
Description: this query has been splitted in 2 queries:

- *First query:* articles are filtered to find the article with the given title. After that, the authors array is exploded to perform a join on its idAuth field with the authors dataframe. Finally, nationalities of the article's authors are collected into a list using the `collect_set`.
  `collect_set`, as the name suggests, discards duplicates, so the final list is a set of nationalities.
- *Second query:* starting from the authors' dataframe, we filtered all the authors whose nationality is present inside the list created with the previous query.

```
nationalities_list = df_articles.filter(f.col("title") == "Locality Sensitive Outlier Detection: A ranking driven approach")\
                                .select(f.explode(df_articles.authors.idAuth).alias("idAuth"))\
                                .join(df_authors, on=f.col("idAuth") == df_authors._id)\
                                .select("nationality")\
                                .agg(f.collect_set("nationality")).collect()[0][0]

df_authors.filter(f.col("nationality")\
          .isin(nationalities_list))\
          .select("name","nationality")\
          .show(truncate=False)
```

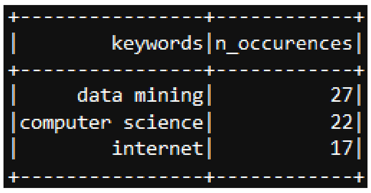

```
+-----------------------+-----------+
|name                   |nationality|
+-----------------------+-----------+
|Ye Wang                |dk         |
|Srinivasan Parthasarathy|jp        |
|Shirish Tatikonda      |gr         |
|Moshe Zukerman         |jp         |
|Michael Wiegand        |jp         |
|GeunSik Jo             |jp         |
|Carla Achury           |gr         |
|Kong-Aik Lee           |jp         |
|Shahram Shah-Heydari   |gr         |
|Wenfang Tan            |dk         |
|Ayoub Alsarhan         |gr         |
|Anjali Agarwal         |jp         |
|David Haccoun          |jp         |
|Silvio Macedo          |dk         |
|John Wan Tung Lee      |gr         |
|Geoff Holmes           |dk         |
|Zornitsa Kozareva      |jp         |
|Peter Murray-Rust      |jp         |
|Rajkumar Buyya         |jp         |
|Srikumar Venugopal     |jp         |
+-----------------------+-----------+
only showing top 20 rows
```

5.2.4. Query 4 - GROUP BY, JOIN, AS

This query finds the 3 most frequent keywords of articles written by italian authors.
Description: starting from the authors dataframe, we keep only italian authors and explode the articles field, renaming the new obtained field to `articles`. After that, duplicates are discarded.
In the second part of the query, we load the full articles's rows using a join. Then, keywords array is exploded. Keywords are grouped and counted. The groups are finally sorted and limited to show the top 3 keywords.

```
df_italian = df_authors.filter(f.col("nationality") == "it")\
                       .select(f.explode("articles")).withColumnRenamed(
                                    "col","articles")\
                       .distinct()

df_keywords = df_italian.join(df_articles, df_italian.articles ==
                                    df_articles._id, "inner")\
                        .select("articles", f.explode("keywords")).
                                    withColumnRenamed("col","keywords")\
                        .groupby("keywords")\
                        .agg(f.count("keywords").alias("n_occurences"))\
                        .sort("n_occurences", ascending=False)\
                        .limit(3).show()
```



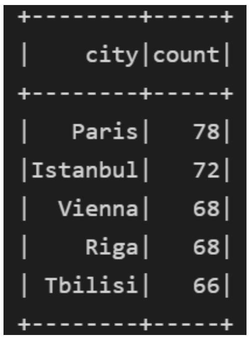
```
+---------------+------------+
|       keywords|n_occurences|
+---------------+------------+
|    data mining|          27|
|computer science|         22|
|       internet|          17|
+---------------+------------+
```

5.2.5. Query 5 - WHERE, GROUP BY

This query finds the cities with more than 65 venues.

Description: the venues dataframe is grouped with respect to the city to perform the count. After that, we keep only cities with more than 65 venues and sort the result in descending order.

```
df_venues\
    .groupby("city")\
    .count()\
    .filter(f.col("count") > 65)\
    .sort("count", ascending=False).show()
```



```
+--------+-----+
|    city|count|
+--------+-----+
|   Paris|   78|
|Istanbul|   72|
|  Vienna|   68|
|    Riga|   68|
| Tbilisi|   66|
+--------+-----+
```

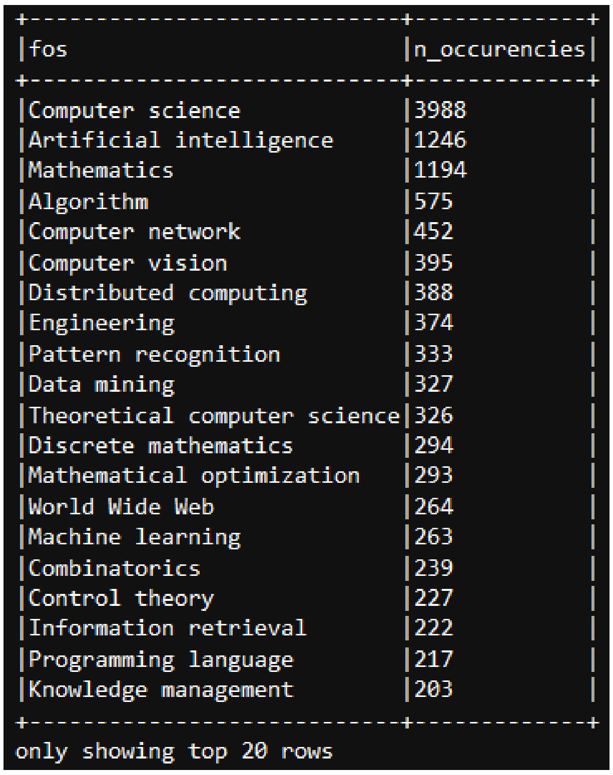
5.2.6. Query 6 - GROUP BY, HAVING, AS

This query finds the field of studies that appears more than 15 times.

Description: We use the explode function to convert the fos array into multiple rows,then we rename the resulting column to `fos`, group by `fos` and count the number of occurrences.

After that, we keep rows with more than 15 occurrences, sort the remaining rows in descending order based on the number of occurrences, and show the top rows.

```
df_articles\
    .select("_id", "title", f.explode("fos")).withColumnRenamed("col", "
                                    fos")\
    .groupby("fos")\
    .agg(f.count("fos").alias("n_occurencies"))\
    .filter(f.col("n_occurencies") > 15)\
    .sort("n_occurencies", ascending=False)\
    .show(truncate=False)
```



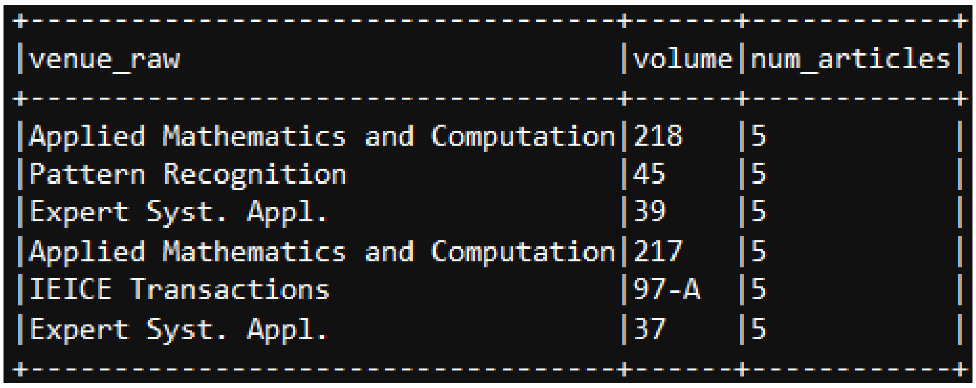
```
+---------------------------+-------------+
|fos                        |n_occurencies|
+---------------------------+-------------+
|Computer science           |3988         |
|Artificial intelligence    |1246         |
|Mathematics                |1194         |
|Algorithm                  |575          |
|Computer network           |452          |
|Computer vision            |395          |
|Distributed computing      |388          |
|Engineering                |374          |
|Pattern recognition        |333          |
|Data mining                |327          |
|Theoretical computer science|326         |
|Discrete mathematics       |294          |
|Mathematical optimization  |293          |
|World Wide Web             |264          |
|Machine learning           |263          |
|Combinatorics              |239          |
|Control theory             |227          |
|Information retrieval      |222          |
|Programming language       |217          |
|Knowledge management       |203          |
+---------------------------+-------------+
only showing top 20 rows
```

5.2.7. Query 7 - WHERE, GROUP BY, HAVING, AS

This query finds all the volumes with at least 5 articles in the dataset, published after 2000.

Description: This query filters the articles in the articles dataframe to only those published after the year 2000, then groups the remaining articles by `venue_raw` and `volume`, counts the number of articles per group, filters the groups to only those with more than 4 articles, and finally displays the results.

```
df_articles\
    .filter(f.col("year") > 2000)\
    .groupby("venue_raw", "volume")\
    .agg(f.count("volume").alias("num_articles"))\
    .filter(f.col("num_articles") > 4)\
    .show(truncate = False)
```



```
+-----------------------------------+------+------------+
|venue_raw                          |volume|num_articles|
+-----------------------------------+------+------------+
|Applied Mathematics and Computation|218   |5           |
|Pattern Recognition                |45    |5           |
|Expert Syst. Appl.                 |39    |5           |
|Applied Mathematics and Computation|217   |5           |
|IEICE Transactions                 |97-A  |5           |
|Expert Syst. Appl.                 |37    |5           |
+-----------------------------------+------+------------+
```

5.2.8. Query 8 - WHERE, NESTED QUERY, GROUP BY

The following query is divided in two queries:

8a. find the venue with highest number of articles

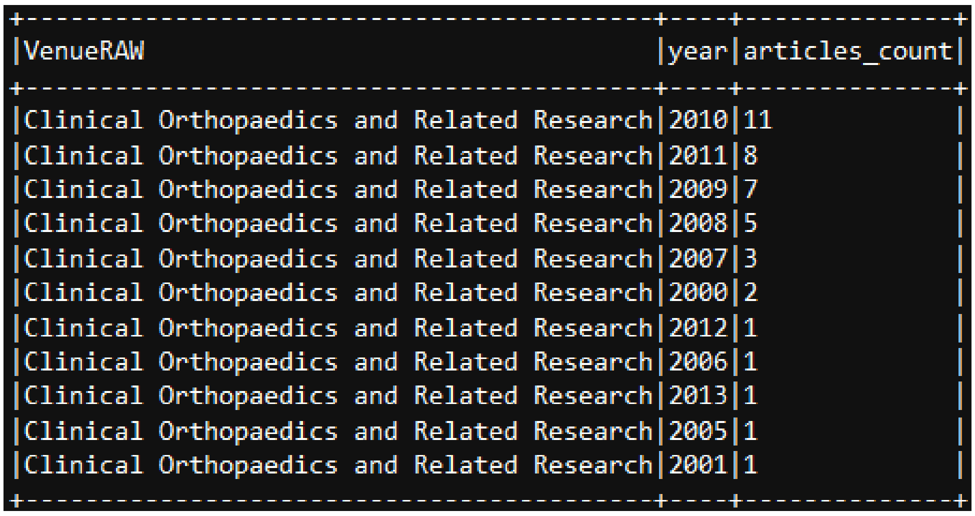
8b. find the number of articles published per year on that venue

Description: the basic functionalities of the two queries are the following

- the *first query* selects the top venue from the venue dataframe based on the size of the `artIds` attribute
- the *second query* filters articles with the selected `venue_raw`, groups the articles by year, and counts the number of articles in each group. Finally, it displays the results projecting over `top_venue`, `year` and `articles_count`

```python
top_venue = df_venues\
                .select("raw",f.size("artIds").alias("count"))\
                .orderBy("count",ascending = False)\
                .limit(1)

df_articles_year = df_articles\
                        .filter(f.col("venue_raw") == top_venue.collect
                            ()[0][0])\
                        .groupBy("year")\
                        .count()\
                        .orderBy("count",ascending=False)\
                        .select(f.lit(top_venue.collect()[0][0]).alias("
                            VenueRAW"),"year",f.col("count").
                            alias("articles_count"))\
                        .show(truncate=False)
```



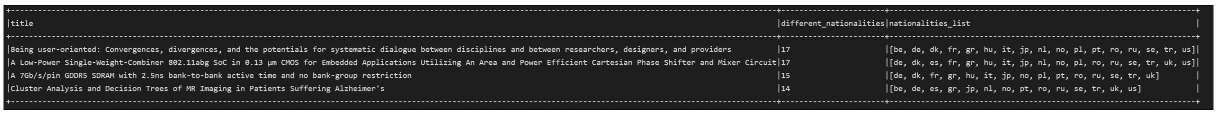
```
+----------------------------------------+----+--------------+
|VenueRAW                                |year|articles_count|
+----------------------------------------+----+--------------+
|Clinical Orthopaedics and Related Research|2010|11            |
|Clinical Orthopaedics and Related Research|2011|8             |
|Clinical Orthopaedics and Related Research|2009|7             |
|Clinical Orthopaedics and Related Research|2008|5             |
|Clinical Orthopaedics and Related Research|2007|3             |
|Clinical Orthopaedics and Related Research|2000|2             |
|Clinical Orthopaedics and Related Research|2012|1             |
|Clinical Orthopaedics and Related Research|2006|1             |
|Clinical Orthopaedics and Related Research|2013|1             |
|Clinical Orthopaedics and Related Research|2005|1             |
|Clinical Orthopaedics and Related Research|2001|1             |
+----------------------------------------+----+--------------+
```

5.2.9. Query 9 - WHERE, GROUP BY, HAVING, 1 JOIN

The following query finds the articles, published after 2000, with more than 13 different nationalities of its authors.

Description: this query filters the articles dataframe by year, exploding the authors array `idAuth` field (note that authors is an array of struct elements with 2 fields). After that, it joins the result with the authors dataframe, groups the articles by id and counts the number of distinct nationalities among the authors. It finally filters the results to include only articles with more than 13 different nationalities and orders the results in descending order, displaying the title of the article, the list of nationalities and their count.

```
df_articles_nationalities = df_articles.alias("art")\
                                .filter(f.col("year") > 2000)\
                                .select("art._id","art.title", f.explode
                                    ("art.authors.idAuth").alias("author
                                    "))\
                                .join(df_authors.alias("auth"), on=f.col
                                    ("author") == df_authors._id)\
                                .groupBy("art._id")\
                                .agg(f.first("title").alias("title"),f.
                                    countDistinct("nationality").alias("
                                    different_nationalities"), f.
                                    collect_set("nationality").alias("
                                    nationalities_list"))\
                                .filter(f.col("different_nationalities")
                                     > 13)\
                                .orderBy("different_nationalities",
                                    ascending=False)\
                                .select("title","different_nationalities",f.sort_array("nationalities_list").alias("nationalities_list"))\
                                .show(truncate=False)
```

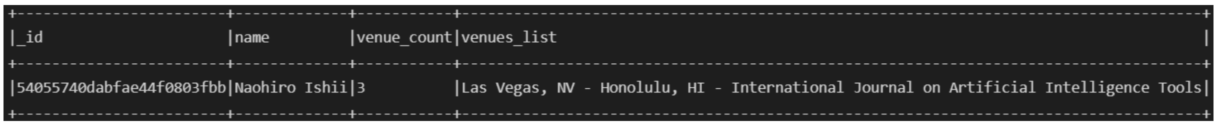


```
+--------------------------------------------------------------------------------------------------------------------------------------------------------------------------+-----------------------+--------------------------------------------------------------------+
|title                                                                                                                                                                     |different_nationalities|nationalities_list                                                  |
+--------------------------------------------------------------------------------------------------------------------------------------------------------------------------+-----------------------+--------------------------------------------------------------------+
|Being user-oriented: Convergences, divergences, and the potentials for systematic dialogue between disciplines and between researchers, designers, and providers          |17                     |[be, de, dk, fr, gr, hu, it, jp, nl, no, pl, pt, ro, ru, se, tr, us]|
|A Low-Power Single-Weight-Combiner 802.11abg SoC in 0.13 µm CMOS for Embedded Applications Utilizing An Area and Power Efficient Cartesian Phase Shifter and Mixer Circuit|17                     |[de, dk, es, fr, gr, hu, it, jp, nl, no, pl, ro, ru, se, tr, uk, us]|
|A 7Gb/s/pin GDDR5 SDRAM with 2.5ns bank-to-bank active time and no bank-group restriction                                                                                 |15                     |[de, dk, fr, gr, hu, it, jp, no, pl, pt, ro, ru, se, tr, uk]        |
|Cluster Analysis and Decision Trees of MR Imaging in Patients Suffering Alzheimer's                                                                                       |14                     |[be, de, es, gr, jp, nl, no, pt, ro, ru, se, tr, uk, us]            |
+--------------------------------------------------------------------------------------------------------------------------------------------------------------------------+-----------------------+--------------------------------------------------------------------+
```

5.2.10. Query 10 - WHERE, GROUP BY, HAVING, 2 JOINS

This query finds all the authors that published on more than 2 Journals.
Description: starting from the authors dataframe, we explode the articles array, creating a new field named `article`. After that, we join the results with the articles collection and then with the venues collection. Then, we filter the results to keep only articles written on journals (type 1) and group by the author id. Finally, we count the number of distinct venues in each group (collecting in a list all the venues of the group), and keep only the groups with more than 2 venues.

```
df_exploded_authors = df_authors.alias("auth")\
                        .select("auth._id","auth.name", f.explode("auth.articles").alias("article"))\
                        .join(df_articles.alias("art"), on=f.col("article") == df_articles._id)\
                        .select("auth._id","auth.name","art._id","art.venue_raw")\
                        .join(df_venues.alias("ven"), on=f.col("venue_raw") == df_venues.raw)\
                        .filter(f.col("type") == 1)\
                        .groupBy("auth._id")\
                        .agg(f.first("name").alias("name"),f.countDistinct("raw").alias("venue_count"),f.concat_ws(" - ",f.collect_set("raw")).alias("venues_list"))\
                        .filter(f.col("venue_count") > 2)\
                        .orderBy("venue_count", ascending=False).show(3, truncate=False)
```



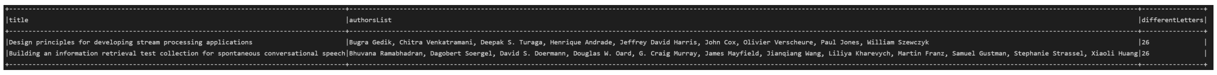
```
+------------------------+------------+-----------+------------------------------------------------------------------------------+
|_id                     |name        |venue_count|venues_list                                                                   |
+------------------------+------------+-----------+------------------------------------------------------------------------------+
|54055740dabfae44f0803fbb|Naohiro Ishii|3          |Las Vegas, NV - Honolulu, HI - International Journal on Artificial Intelligence Tools|
+------------------------+------------+-----------+------------------------------------------------------------------------------+
```

5.2.11. Query 11 - EXTRA

This query returns all the articles written by authors whose names combined have all 26 letters of the alphabet.

Description: The query starts with exploding articles for each author. Then, the grouping combined with the collect retrieves, for each article, the list of its authors, then several operation are applied on this list in order to obtain the different letters that are present in the list of authors. After that, a filter to keep only the ones that have all the 26 letters of the alphabet in it is applied, and the result is joined with articles to obtain the title. Finally, a projection is used to display the title and the list of authors in alphabetical order.

```python
df_authors.select("name", f.explode("articles").alias("idArt")) \
          .groupBy("idArt") \
          .agg(f.collect_set("name").alias("authorsList")) \
          .select("idArt", "authorsList", (f.size(f.array_distinct(f.split(f.regexp_replace(f.lower(f.concat_ws("", "authorsList")), "[^a-z]", ""), "")))-1).alias("differentLetters")) \
          .filter(f.col("differentLetters") == 26)\
          .join(df_articles, on=f.col("idArt") == df_articles._id) \
          .select("title", f.concat_ws(", ", f.sort_array("authorsList")).alias("authorsList"), "differentLetters") \
          .show(truncate=False)
```



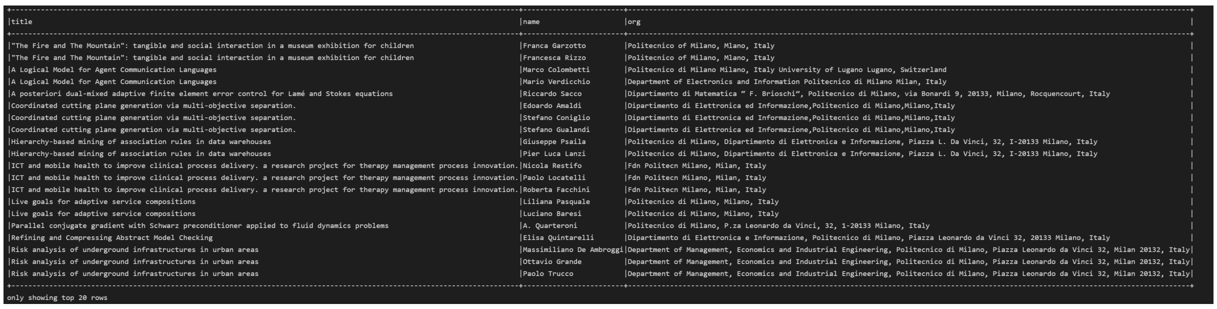
```
+-----------------------------------------------------------------+------------------------------------------------------------------------------------------------------------------------------------------------------------------------+---------------+
|title                                                            |authorsList                                                                                                                                                             |differentLetters|
+-----------------------------------------------------------------+------------------------------------------------------------------------------------------------------------------------------------------------------------------------+---------------+
|Design principles for developing stream processing applications  |Bugra Gedik, Chitra Venkatramani, Deepak S. Turaga, Henrique Andrade, Jeffrey David Harris, John Cox, Olivier Verscheure, Paul Jones, William Szewczyk                |26             |
|Building an information retrieval test collection for spontaneous conversational speech|Bhuvana Ramabhadran, Dagobert Soergel, David S. Doermann, Douglas W. Oard, G. Craig Murray, James Mayfield, Jianqiang Wang, Liliya Kharevych, Martin Franz, Samuel Gustman, Stephanie Strassel, Xiaoli Huang|26             |
+-----------------------------------------------------------------+------------------------------------------------------------------------------------------------------------------------------------------------------------------------+---------------+
```

5.2.12. Query 12 - EXTRA

This query returns all articles written in affiliation with *Politecnico of Milano*.

Description: the query starts by exploding the authors array field in the article, creating the new **affiliation** attribute. Articles that contain at least one of the desired organization (the same article could be written in collaboration with different universities) are kept. Then, a join with the authors collection is executed to retrieve the name of the author.

```
df_articles\
    .select("title",f.explode("authors").alias("affiliation"))\
    .filter(f.col("affiliation.org").like("%Poli%Mil%"))\
    .join(df_authors, on=f.col("affiliation.idAuth") == df_authors._id)
    \
    .select("title", "name", "affiliation.org") \
    .orderBy("title","name")\
    .show(truncate=False)
```



```
+-------------------------------------------------------------------------------------------------------------------------+------------------------+--------------------------------------------------------------------------------------------------------------------------------------+
|title                                                                                                                    |name                    |org                                                                                                                                   |
+-------------------------------------------------------------------------------------------------------------------------+------------------------+--------------------------------------------------------------------------------------------------------------------------------------+
|"The Fire and The Mountain": tangible and social interaction in a museum exhibition for children                         |Franca Garzotto         |Politecnico of Milano, Mlano, Italy                                                                                                   |
|"The Fire and The Mountain": tangible and social interaction in a museum exhibition for children                         |Francesca Rizzo         |Politecnico of Milano, Mlano, Italy                                                                                                   |
|A Logical Model for Agent Communication Languages                                                                        |Marco Colombetti        |Politecnico di Milano Milano, Italy University of Lugano Lugano, Switzerland                                                          |
|A Logical Model for Agent Communication Languages                                                                        |Mario Verdicchio        |Department of Electronics and Information Politecnico di Milano Milan, Italy                                                          |
|A posteriori dual-mixed adaptive finite element error control for Lamé and Stokes equations                              |Riccardo Sacco          |Dipartimento di Matematica “ F. Brioschi”, Politecnico di Milano, via Bonardi 9, 20133, Milano, Rocquencourt, Italy                   |
|Coordinated cutting plane generation via multi-objective separation.                                                     |Edoardo Amaldi          |Dipartimento di Elettronica ed Informazione,Politecnico di Milano,Milano,Italy                                                        |
|Coordinated cutting plane generation via multi-objective separation.                                                     |Stefano Coniglio        |Dipartimento di Elettronica ed Informazione,Politecnico di Milano,Milano,Italy                                                        |
|Coordinated cutting plane generation via multi-objective separation.                                                     |Stefano Gualandi        |Dipartimento di Elettronica ed Informazione,Politecnico di Milano,Milano,Italy                                                        |
|Hierarchy-based mining of association rules in data warehouses                                                          |Giuseppe Psaila         |Politecnico di Milano, Dipartimento di Elettronica e Informazione, Piazza L. Da Vinci, 32, I-20133 Milano, Italy                      |
|Hierarchy-based mining of association rules in data warehouses                                                          |Pier Luca Lanzi         |Politecnico di Milano, Dipartimento di Elettronica e Informazione, Piazza L. Da Vinci, 32, I-20133 Milano, Italy                      |
|ICT and mobile health to improve clinical process delivery. a research project for therapy management process innovation.|Nicola Restifo          |Fdn Politecn Milano, Milan, Italy                                                                                                     |
|ICT and mobile health to improve clinical process delivery. a research project for therapy management process innovation.|Paolo Locatelli         |Fdn Politecn Milano, Milan, Italy                                                                                                     |
|ICT and mobile health to improve clinical process delivery. a research project for therapy management process innovation.|Roberta Facchini        |Fdn Politecn Milano, Milan, Italy                                                                                                     |
|Live goals for adaptive service compositions                                                                             |Liliana Pasquale        |Politecnico di Milano, Milano, Italy                                                                                                  |
|Live goals for adaptive service compositions                                                                             |Luciano Baresi          |Politecnico di Milano, Milano, Italy                                                                                                  |
|Parallel conjugate gradient with Schwarz preconditioner applied to fluid dynamics problems                               |A. Quarteroni           |Politecnico di Milano, P.za Leonardo da Vinci, 32, 1-20133 Milano, Italy                                                              |
|Refining and Compressing Abstract Model Checking                                                                         |Elisa Quintarelli       |Dipartimento di Elettronica e Informazione, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milano, Italy                   |
|Risk analysis of underground infrastructures in urban areas                                                              |Massimiliano De Ambroggi|Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Piazza Leonardo da Vinci 32, Milan 20132, Italy|
|Risk analysis of underground infrastructures in urban areas                                                              |Ottavio Grande          |Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Piazza Leonardo da Vinci 32, Milan 20132, Italy|
|Risk analysis of underground infrastructures in urban areas                                                              |Paolo Trucco            |Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Piazza Leonardo da Vinci 32, Milan 20132, Italy|
+-------------------------------------------------------------------------------------------------------------------------+------------------------+--------------------------------------------------------------------------------------------------------------------------------------+
only showing top 20 rows
```

6 | Conclusions

Spark is a computing platform designed to efficiently scale data processing and analysis. Indeed, given its distributed framework and the use of RDDs, it allows splitting the workload across multiple nodes. Furthermore, Spark offers a rich set of APIs and libraries, making it a versatile tool for working with big data. In our implementation, we used the PySpark interface, which makes the interaction with Apache very intuitive. The flexibility offered by the RDDs made it possible to shape the data structure to match our needs.

In the end, the technologies used in the project, allowed us to face, from different perspectives, the challenges of designing efficient database solutions for large sets of data.